CLAIMS

1. A method for detecting a crater end of a continuously cast product, the method comprising the steps of installing an ultrasonic shear wave sensor for transmitting an ultrasonic shear wave to the continuously cast product and receiving the transmitted ultrasonic shear wave and an ultrasonic longitudinal wave sensor for transmitting an ultrasonic longitudinal wave to the continuously cast product and receiving the transmitted ultrasonic longitudinal wave at the same position in a continuous casting machine or at two positions apart from each other in a casting direction but at the same position in a transverse direction of the cast product, detecting based on variations of an ultrasonic signal received by the ultrasonic shear wave sensor that the crater end of the cast product is matched with the installed position of the ultrasonic shear wave sensor, calibrating a calculation formula for determining the crater end from a propagation time of an ultrasonic longitudinal wave signal such that the crater end computed from the propagation time of the ultrasonic longitudinal wave signal at that time is matched with the installed position of the ultrasonic shear wave sensor, and after the calibration, determining the crater end from the propagation time of the ultrasonic longitudinal wave signal

based on the calibrated calculation formula.

2. The method for detecting a crater end of a continuously cast product according to Claim 1, further comprising the steps of installing a second ultrasonic shear wave sensor downstream of said ultrasonic shear wave sensor in the casting direction at the same position in the transverse direction of the cast product, detecting based on variations of an ultrasonic signal received by the second ultrasonic shear wave sensor that the crater end of the cast product is matched with the installed position of the second ultrasonic shear wave sensor, and further calibrating the calculation formula for determining the crater end from the propagation time of the ultrasonic longitudinal wave signal such that the crater end computed from the propagation time of the ultrasonic longitudinal wave signal at that time is matched with the installed position of the second ultrasonic shear wave sensor.

3. The method for detecting a crater end of a continuously cast product according to Claim 1 or 2, wherein the calculation formula for determining the crater end from the propagation time of the ultrasonic longitudinal wave signal differs between when the crater end is positioned upstream of the installed position of the ultrasonic

longitudinal wave sensor in the casting direction and when the crater end is positioned downstream thereof.

4. A method for detecting a crater end of a continuously cast product, the method comprising the steps of installing an ultrasonic shear wave sensor for transmitting an ultrasonic shear wave to the continuously cast product and receiving the transmitted ultrasonic shear wave in a continuous casting machine, detecting based on variations of an ultrasonic signal received by the ultrasonic shear wave sensor that the crater end of the cast product is matched with the installed position of the ultrasonic shear wave sensor, calibrating a physical property value used in calculation based on a heat condition equation such that the crater end computed based on the heat condition equation using casting conditions at that time is matched with the installed position of the ultrasonic shear wave sensor, and after the calibration, determining the crater end by the calculation based on the heat condition equation under respective casting conditions by using the calibrated physical property value.

5. A method for detecting a crater end of a continuously cast product, the method comprising the steps of installing an ultrasonic shear wave sensor for transmitting an

ultrasonic shear wave to the continuously cast product and receiving the transmitted ultrasonic shear wave in a continuous casting machine, detecting based on variations of an ultrasonic signal received by the ultrasonic shear wave sensor that the crater end of the cast product is matched with the installed position of the ultrasonic shear wave sensor, calibrating a physical property value used in calculation based on a heat condition equation such that the crater end computed based on the heat condition equation using casting conditions at that time is matched with the installed position of the ultrasonic shear wave sensor, determining the crater ends by the calculation based on the heat condition equation by using the calibrated physical property value and measuring the propagation times by the ultrasonic shear wave sensor under various casting conditions, obtaining a relationship between the crater ends computed based on the heat condition equation and the propagation times measured by the ultrasonic shear wave sensor, and determining the crater end from the propagation time measured by the ultrasonic shear wave sensor based on the obtained relationship.

6. A method for detecting a crater end of a continuously cast product, the method comprising the steps of installing, in a continuous casting machine, a first ultrasonic shear

wave sensor for transmitting an ultrasonic shear wave to the continuously cast product and receiving the transmitted ultrasonic shear wave and at least one of an ultrasonic longitudinal wave sensor for transmitting an ultrasonic longitudinal wave to the continuously cast product and receiving the transmitted ultrasonic longitudinal wave and a second ultrasonic shear wave sensor for transmitting an ultrasonic shear wave and receiving the transmitted ultrasonic shear wave, detecting based on variations of an ultrasonic signal received by the first ultrasonic shear wave sensor that the crater end of the cast product is matched with the installed position of the first ultrasonic shear wave sensor, calibrating a physical property value used in calculation based on a heat condition equation such that the crater end computed based on the heat condition equation using casting conditions at that time is matched with the installed position of the first ultrasonic shear wave sensor, determining the crater ends by the calculation based on the heat condition equation by using the calibrated physical property value and measuring the propagation times by the ultrasonic longitudinal wave sensor or the second ultrasonic shear wave sensor under various casting conditions, obtaining a relationship between the crater ends computed based on the heat condition equation and the propagation times measured by the ultrasonic longitudinal

wave sensor or the second ultrasonic shear wave sensor, and determining the crater end from the propagation time measured by the ultrasonic longitudinal wave sensor or the second ultrasonic shear wave sensor based on the obtained relationship.

7. A method for detecting a crater end of a continuously cast product, the method comprising the step of, from a propagation time of an ultrasonic longitudinal wave signal measured by an ultrasonic longitudinal wave sensor installed in the continuous casting machine for which the calibration has been made or in a different continuous casting machine, determining the crater end in the relevant continuous casting machine by using the calculation formula calibrated by the method according to any one of Claims 1 to 3.

8. A method for detecting a crater end of a continuously cast product, the method comprising the steps of executing the calculation based on the heat condition equation by using the physical property value calibrated by the method according to Claim 4 and the casting conditions of the continuous casting machine for which the calibration has been made or of a different continuous casting machine, and determining the crater end in the relevant continuous casting machine.

9. A method for detecting a crater end of a continuously cast product, the method comprising the step of, based on the relationship between the crater ends computed based on the heat condition equation and the propagation times measured by the ultrasonic sensor, which is obtained by the method according to Claim 5 or 6, determining the crater end in a target continuous casting machine from a propagation time of an ultrasonic signal measured by an ultrasonic shear wave sensor or an ultrasonic longitudinal wave sensor installed in the continuous casting machine for which said relationship has been obtained or in a different continuous casting machine.

10. A method for detecting a crater end of a continuously cast product, the method comprising the steps of determining the crater end of the cast product by the method for detecting a crater end of a continuously cast product according to any one of Claims 1 to 6, and adjusting a casting speed or intensity of secondary cooling for the cast product in accordance with the determination result.

11. An apparatus for detecting a crater end of a continuously cast product, the apparatus comprising an ultrasonic shear wave sensor made up of an ultrasonic shear

wave transmitter for transmitting an ultrasonic shear wave to the continuously cast product and an ultrasonic shear wave receiver for receiving the transmitted ultrasonic shear wave, an ultrasonic longitudinal wave sensor made up of an ultrasonic longitudinal wave transmitter for transmitting an ultrasonic longitudinal wave to the continuously cast product and an ultrasonic longitudinal wave receiver for receiving the transmitted ultrasonic longitudinal wave, the ultrasonic longitudinal wave sensor being installed at the same position in a continuous casting machine as the ultrasonic shear wave sensor or a position apart from the ultrasonic shear wave sensor in a casting direction but at the same position in a transverse direction of the cast product, and a crater end computing unit for determining the crater end of the cast product by using a calculation formula in accordance with an ultrasonic signal received by the ultrasonic longitudinal wave sensor, wherein at the time when it is confirmed based on variations of an ultrasonic signal received by the ultrasonic shear wave sensor that the installed position of the ultrasonic shear wave sensor and the crater end of the cast product are matched with each other, the calculation formula is calibrated such that the crater end computed based on the calculation formula is matched with the installed position of the ultrasonic shear wave sensor.

12. The apparatus for detecting a crater end of a continuously cast product according to Claim 11, further comprising a second ultrasonic shear wave sensor installed downstream of said ultrasonic shear wave sensor in the casting direction at the same position in the transverse direction of the cast product, wherein at the time when it is confirmed based on variations of an ultrasonic signal received by the second ultrasonic shear wave sensor that the installed position of the second ultrasonic shear wave sensor and the crater end of the cast product are matched with each other, the calculation formula is further calibrated such that the crater end computed based on the calculation formula is matched with the installed position of the second ultrasonic shear wave sensor.

13. The apparatus for detecting a crater end of a continuously cast product according to Claim 11 or 12, wherein the ultrasonic shear wave transmitter and the ultrasonic longitudinal wave transmitter are installed on one side of the cast product, the ultrasonic shear wave receiver and the ultrasonic longitudinal wave receiver are installed on the other side of the cast product, and a set of the ultrasonic shear wave transmitter and the ultrasonic longitudinal wave transmitter and a set of the ultrasonic

shear wave receiver and the ultrasonic longitudinal wave receiver are each constituted as an integral electromagnetic ultrasonic sensor having three or more magnetic poles in the transverse direction of the cast product and made up of a longitudinal wave coil arranged to wind the surrounding of an inner magnetic pole aside from a surface thereof and a shear wave coil arranged to overlie the magnetic pole surface.

14. An apparatus for detecting a crater end of a continuously cast product, the apparatus comprising an ultrasonic shear wave sensor made up of an ultrasonic shear wave transmitter for transmitting an ultrasonic shear wave to the continuously cast product and an ultrasonic shear wave receiver for receiving the transmitted ultrasonic shear wave, and a heat condition equation unit for executing calculation based on a heat condition equation in accordance with casting conditions and values of physical properties, thereby determining the crater end of the cast product, wherein at the time when it is confirmed based on variations of an ultrasonic signal received by the ultrasonic shear wave sensor that the installed position of the ultrasonic shear wave sensor and the crater end of the cast product are matched with each other, at least one of the values of physical properties used in the calculation based on the

heat condition equation is calibrated such that the crater end computed by the heat condition equation unit is matched with the installed position of the ultrasonic shear wave sensor.

15. An apparatus for detecting a crater end of a continuously cast product, the apparatus comprising an ultrasonic shear wave sensor made up of an ultrasonic shear wave transmitter for transmitting an ultrasonic shear wave to the continuously cast product and an ultrasonic shear wave receiver for receiving the transmitted ultrasonic shear wave, a heat condition equation unit for executing calculation based on a heat condition equation in accordance with casting conditions and values of physical properties, thereby determining the crater end of the cast product, and a crater end estimating unit for estimating the crater end of the cast product based on a relationship between an ultrasonic signal received by the ultrasonic shear wave sensor and the crater end computed by the heat condition equation unit, wherein at the time when it is confirmed based on variations of the ultrasonic signal received by the ultrasonic shear wave sensor that the installed position of the ultrasonic shear wave sensor and the crater end of the cast product are matched with each other, at least one of the values of physical properties used in the calculation

based on the heat condition equation is calibrated such that the crater end computed by the heat condition equation unit is matched with the installed position of the ultrasonic shear wave sensor, wherein after the calibration of the physical property value, the crater end estimating unit obtains a relationship between the ultrasonic signal received by the ultrasonic shear wave sensor and the crater end computed by the heat condition equation unit, and wherein the crater end is determined from a propagation time measured by the ultrasonic shear wave sensor based on the obtained relationship.

16. An apparatus for detecting a crater end of a continuously cast product, the apparatus comprising an ultrasonic shear wave sensor made up of an ultrasonic shear wave transmitter for transmitting an ultrasonic shear wave to the continuously cast product and an ultrasonic shear wave receiver for receiving the transmitted ultrasonic shear wave, an ultrasonic longitudinal wave sensor made up of an ultrasonic longitudinal wave transmitter for transmitting an ultrasonic longitudinal wave to the continuously cast product and an ultrasonic longitudinal wave receiver for receiving the transmitted ultrasonic longitudinal wave, a heat condition equation unit for executing calculation based on a heat condition equation in accordance with casting

conditions and values of physical properties, thereby determining the crater end of the cast product, and a crater end estimating unit for estimating the crater end of the cast product based on a relationship between an ultrasonic signal received by the ultrasonic shear wave sensor and the crater end computed by the heat condition equation unit, wherein at the time when it is confirmed based on variations of the ultrasonic signal received by the ultrasonic shear wave sensor that the installed position of the ultrasonic shear wave sensor and the crater end of the cast product are matched with each other, at least one of the values of physical properties used in the calculation based on the heat condition equation is calibrated such that the crater end computed by the heat condition equation unit is matched with the installed position of the ultrasonic shear wave sensor, wherein after the calibration of the physical property value, the crater end estimating unit obtains a relationship between an ultrasonic signal received by the ultrasonic longitudinal wave sensor and the crater end computed by the heat condition equation unit, and wherein the crater end is determined from a propagation time measured by the ultrasonic longitudinal wave sensor based on the obtained relationship.